The ability of the Data Set 202 to transmit information over the regular telephone network makes it one of the most flexible and economical instruments of modern communications.

An FM Data Set for Voiceband Data Transmission

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IN THIS AGE of automation, computing machines are performing more and more of our routine business and scientific chores with unmatched speed and accuracy. Data-handling and data-processing have become large, complex fields and are daily becoming ever larger and still more complex. The increasing use of digital equipment requires communications techniques which enable machines to "talk" to machines in a variety of ways and at any distance apart. This, in turn, creates an area of vital interest to the telephone system where there exists an extensive nation-wide communication network ready to serve a wide variety of new data needs.

The FM data set developed at the Laboratories is one of several data sets designed to transmit information over the voice-band telephone network. In its role as coupling unit between the business machine and the telephone line, it operates on binary sequential data; the output at the receiver appears as a recovered copy of the data input at the transmitter. The bit (*bi*nary digi*t*) speed, within broad limits, is entirely under the control of the business machine.

Frequency moduation is used because it allows signals to be correctly recovered despite sudden amplitude changes of the carrier during wire-line transmission. Any signal-to-noise advantage resulting from the use of frequency modulation in this application is usually small because of the character of wire-line noise and because of the small deviation ratio usually used to obtain the utmost in transmission speed.

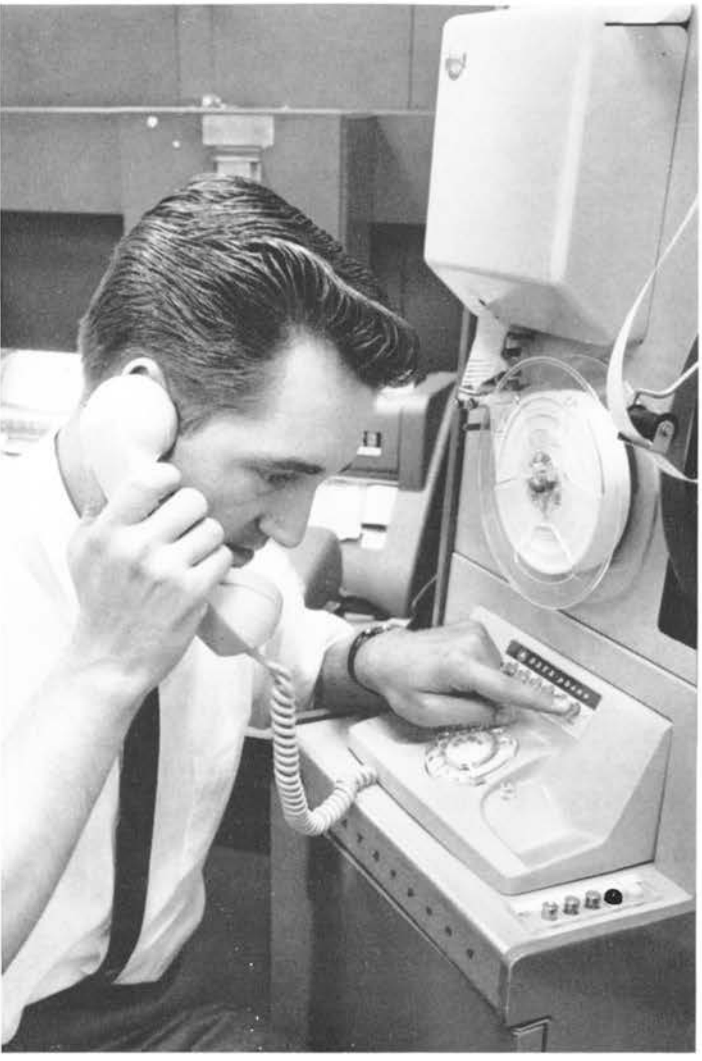
The frequency deviation itself, however, is relatively large—nearly two to one—with the modulated signal swinging between so-called "mark" and "space" frequencies of 1200 and 2200 cycles respectively. Furthermore, with a modulating rate exceeding 1200 bits per second, a mark bit contains less than one cycle of the mark frequency. This generates a carrier interference problem in the lower sideband requiring special design consideration in the data set.

Operational requirements such as these are necessary to insure high efficiency in the use of voice-frequency telephone circuits for data transmission. The most economical design of a set to meet such requrements involves the use of relatively simple circuits. Accordingly, in desiging the FM data set, Laboratories engineers made extensive use of digital techniques to attain the necessary accuracy. They designed the set so that no adjustments would be needed even in manufacture.

The data set is extraordinarily versatile. It may be installed for two-wire or four-wire operation with or without a telephone and with manual or automatic answering of data calls. The data set can be tested from a central test location in the telephone plant. Customers have a choice of two transmitting levels (0 and –6 dbm), two line impedances (600 and 900 ohms), and they have the option of having the set operate with or without delay or amplitude compromise equalizers.

There are two types of FM data sets: one—with the telephone as an integral part of the set—is known as the Data Set 202A and operates on a two-wire basis; the other—where the telephone is separated from the data set—is known as the Data Set 202B and operates in either a two-wire or four-wire arrangement. In two-wire operation, both types generally work on voice channels in the switched telephone network with data speeds presently limited to 1200 bits per second. However, on private lines—where the communication link is fixed and the amplitude is equalized by using special delay circuits — a maximum speed of 1600 bits per second is expected to be offered.

The data set is made up of three basic circuits: the transmitter, the receiver, and the control circuitry. These circuits are shown on page 5. The transmitter and receiver are transistorized and use simple modulation and demodulation techniques; that is, voltage control of a multivibrator frequency at the transmitter and zero crossing detection at the receiver. The control circuitry is composed mostly of relays, which, when used with suitable strapping arrangements



E. R. Bay and Miss G. B. Newmier demonstrate how the Data Set 202 A is used to transmit information between two data points. Both parties are about to press the DATA button which permits the transfer of information. At the end of transmission, the data set is automatically turned off.

or with pushbuttons associated with the telephone, allows for changing the modes of terminal operation. The data set operates within close tolerances on plus and minus dc voltages derived from a simple unregulated 115-volt 60-cycle power supply.

Data sets with telephones have four pushbuttons which control the modes of operation. When a customer presses the TALK button, the telephone can be used in the usual way for dialing and talking. When he presses the DATA button, the set changes to the data mode. With the telephone on hook, interlocking safeguards prevent the accidental operation of any of the buttons from interrupting a data call. Only by lifting the telephone and pushing the TALK button can a data call be interrupted.

An AUTO button switches the data set from a manual to an automatic mode for answering data calls. It too, has interlocking safeguards which insure that the terminal and data-processing equipment are in operational readiness. A TEST button switches the set to a mode which permits testing from a central test location in the telephone plant. There are two extra buttons which permit the telephone to be used for talking on other telephone lines at the data-set location. These buttons may be operated without interrupting data transfer.

The block drawing on page 5 shows the data set in the two-wire configuration. The four-wire configuration is obtained by rearranging certain connections in the control circuit and splitting the line connections between the transmitter and receiver to allow independent transmit and receive paths. A four-wire telephone may also be used in this configuration.

The transmitter circuitry is shown in block form at the top of the drawing on the next page. Transmitting starts when a business machine initiates a request-to-send signal by switching from —3 volts to +3 volts on the interchange lead assigned to this function. The request-to-send control in the data set is a transistor switch which closes and starts the multivibrator and the clear-to-send circuit. The clear-to-send circuit consists of a two-stage transistor amplifier and a resistor-capacitor timing network. About 200 milliseconds after the request-to-send operates, the timing network switches the clear-to-send output from —8 volts to +8 volts, at which time the business machine may start sending data on the data-in lead. During this time, the communication channel is prepared for data transmission.

The multivibrator uses two transistors and precision resistor-capacitor cross-coupling networks. Its frequency depends on the voltage applied at the junction of the two network resistors leading to the transistor bases. A typical range of frequency variation versus voltage input is shown on page 6. The characteristic is substantially linear.

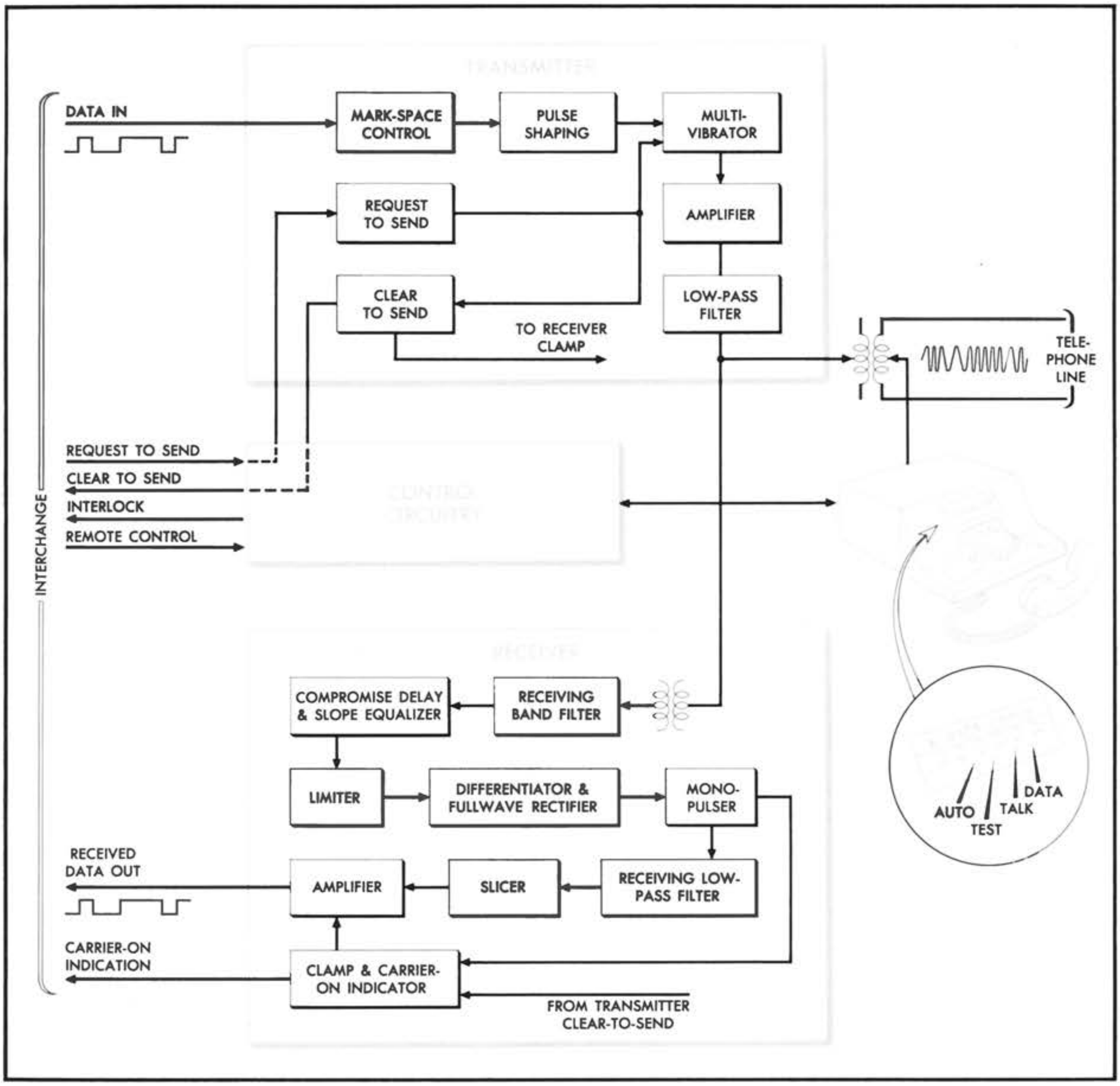
To shift the frequency of the multivibrator precisely between mark and space frequencies, a mark-to-space control is interposed between the send-data input and the voltage input to the multivibrator. This control circuit consists of a two-stage transistor gate in which a send-data input voltage of at least —3 volts and +3 volts (representing respectively mark and space inputs) causes the gate output to go from a low to a high-impedance condition. This causes precise changes in output voltage of a resistance-divider network at the input to the multivibrator.

To make frequency control independent of supply voltage changes, the divider network is placed across ground and the power supply to the multivibrator. A resistance-capacitor pulse-shaping network is interposed between the divider and the multivibrator. This network limits higher data-pulse frequency components thereby reducing certain disturbing effects of the corresponding lower sideband frequency components appearing in the carrier band.

The multivibrator output is isolated from the transmission line by a single transistor amplifier. The amplifier is followed by a low-pass filter having only sufficient attenuation to suppress harmonics of the carrier to tolerable levels on the telephone line. The filter output circuit is high impedance so that it may, in two-wire applications, be bridged across the receiver input without serious loss of receiver sensitivity. The sending level may be wired for 0 dbm or —6 dbm output.

The receiving circuit is shown in block form in the lower part of the drawing opposite. The FM signal received from the line passes through a repeating coil and a constant-resistance receiving band filter with a pass-band characteristic centered around the mean of the 1200- and 2200-cycle mark-and-space frequencies. The signal then passes through a constant-resistance line-delay equalizer and slope equalizer circuit to the input of the limiter. All of this circuitry terminates the repeating coil in a fixed resistance. Taps on the repeating coil allow the line to be terminated in 600 or 900 ohms.

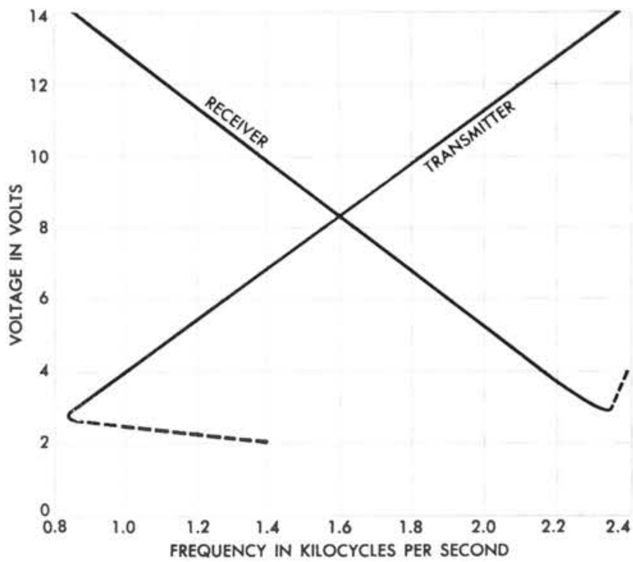
The remainder of the receiving circuit consists of the following components: a limiter, which converts the received sinusoidal input to a corresponding square-wave output; a differentiator,



Over-all block diagram of the Data Set 202 A and B. The set can transmit information over the regular switched telephone network or over private lines. It is readily adaptable and economical for both commercial and industrial applications involving data transfer over any distance.

which provides a voltage output only at the transitions of the square wave; a monopulser, which measures out a fixed amount of energy for every transition of the square wave developed by the differentiator; a low pass filter, which clears away all unwanted frequency components leaving an average voltage output which varies in proportion to the received frequency input; an output slicer-amplifier which makes a decision at a specific value of the average filter ouput voltage to indicate mark or space and then saturates correspondingly to give, at the received-data output, −8 volts for mark and +8 volts for space.

The received data output is a copy of signal input to the transmitter. It is applied to an interchange lead assigned for the purpose and passed on to the business machine. To prevent troublesome outputs caused by sporadic noise hits while the receiver is on line and no received carrier is present, a "clamping" or inhibiting circuit holds the data output in the −8 volt marking condition. When steady carrier has been received for 40 milliseconds, the holding condition is removed. The clamp stays off until carrier is removed for 15



Curves show linearity of the modulation and demodulation processes in terms of voltage input at modulator and voltage output at demodulator.

milliseconds or more. The 15 millisecond holdover prevents clamping on occasional short interruptions of the carrier tranmission.

On two-wire circuits without echo suppressors or where echo suppressors have been disabled for data transmission, some form of echo suppression must be provided in the data terminal. This is required when a customer has just finished transmiting from a two-wire terminal and wishes, for example, to receive some sort of confirming signal from the distant terminal. Upon termination of a transmission cycle, the request to send is operated from a positive to a negative voltage causing the transmitter to go off and the clear-to-send output to go immediately from +8 to −8 volts. This initiates a "squelch", or blanking action in the receiver data output and echo voltages from the transmission cycle appearing at the receiver input are prevented from giving a received data output for about 80 milliseconds. The time is long enough to insure echo suppression over the longest round-trip echo path in the switched telephone network.

The control circuit is a complex of relays and pushbuttons interconnected to provide the means for controlling the terminal. As described previously, the circuit performs several more or less unrelated functions.

There are two ways of answering a data call at the receiver. Attended answering is manual; a person first has to answer the telephone and then, upon verbal arrangement with the calling party, switch from the talk-mode to the data-mode by pressing the DATA button on the phone. In the data-mode, the data set is normally in the receiving condition. The transmitting condition is established when the data-processing circuitry, after receiving a positive interlock voltage from the data set, places +3 volts or more on the request-to-send input. Data transmission may then proceed after a minimum delay for line conditioning. Thereafter, transmission in either direction may take place automatically in accordance with instruction codes in the message and the states of the interchange control leads set by the data-processing equipment and the data set.

Unattended answering is an automatic receiving function which is established by the operation of the AUTO button or by a permanently wired-in automatic condition. When a call is received in this mode, the received ringing current pumps a resistance-capacitor tank circuit until enough current is available to operate a ringing relay. The pumping is required to insure against operation of this relay on unwanted interference. The operation of this relay provides, among other things, a closure on the ring-indicator leads to the data-processing equipment so that this equipment may be set in motion in anticipation of the data to follow.

To indicate a ready condition, the data-processing equipment provides a closure between the three leads called ready, remote-control-common, and remote-release. Under these conditions, after ringing has been received, a 1200-cycle tone is then sent to the transmitting terminal at the far end signifying to the attendant there that the receiver is ready to receive data. Transmission may then take place in the usual manner with alternate transmission and reception controlled by the data-processing equipment. Upon completion of a call, a code word can cause the receiving data-processing equipment to open the remote release lead and drop the receiver off the line, or the carrier may be removed for the same purpose. If either should fail, an automatic feature in most central offices causes a disconnect about 30 seconds after the transmitting terminal has gone off line.

Another feature of the data set is remote testing. When trouble is suspected, remote techniques can be used to check out the equipment for any gross malfunction before a telephone craftsman is dispatched to the site. The testing is done at a control testing location in the telephone plant by means of tones sent over the telephone line. To check the Data Set 202, the attendant at the test center first makes telephone contact with someone at the data terminal. He then places a 1200-cycle test tone on the line which is the cue to push the test button and place the terminal in the test mode. In this mode, all important interchange leads to the data-processing equipment are disconnected from the data set with all output leads given negative or idle mode potentials. At the same time, suitable interconnections are made between receiver output, transmitter input and certain control functions. The connections are made so that the largest number of data-set functions are tested. Maximum load is placed on all output leads and minimum input is applied to all input leads.

When the test button is pressed and the associated lamp remains lighted (indicating test in progress), the attendant hangs up and waits for a call from the test center informing him of the test results. The tester may now proceed with the testing. The 1200-cycle tone from the test center (the mark frequency) is derived from a calibrated oscillator. The tester listens for the transmitted tone as well as for the tone coming back from the data terminal. To ascertain whether there are any defects in most of the interface inputs and outputs as well as to determine the receiver slicing and the accuracy of the mark and space frequencies coming from the data set, the tester slides the oscillator frequency up and down in prescribed sequences between mark and space frequencies. The tester may also estimate transmitter send level and receiver sensitivity if he knows the line loss. By suitable filtering and test tone offset, he may select the specific tone from the data set and measure its level. Similarly, he may measure the oscillator level at which the data set drops off the line (it is held on line through the "carrier-on" indicator).

During the testing, the tones from the data set are interrupted internally by means of a "flasher" or timer circuit which switches the tones "on" and "off" at about one second intervals. This prevents the data set from locking itself into one state during testing.

The Data Sets 202A and 202B are designed for use in the medium speed range of approximately 200 to 1600 bits per second. An effort has been made to incorporate as much flexibility as possible for coupling business machines together through a voice-frequency channel. The unattended, receiving mode is part of the step required for machines to "talk" to machines without human intervention. The development and widespread use of these and related sets brings closer the day when communication facilities may handle more data than voice calls and "conversations" between machines may exceed in bulk those between people.

Telstar II to be Launched in Spring

A second Telstar will be launched in the spring of 1963, according to a recent announcement by the A.T.&T. Co. An important objective of Telstar II is to learn how to extend satellite life by avoiding or overcoming radiation damage. It was radiation which disabled Telstar I's command circuit after four months of successful operation (see story on page 22).

Telstar II will be launched for A.T.&T. by the National Aeronautics and Space Administration, with the company paying all costs for launching as it did for Telstar I.

Bell Laboratories, creator of Telstar, has been studying various means of reducing the radiation damage from the time its intensity became apparent. Among the possibilities are additional shielding for the satellite, and placing it in an orbit more suitable than the orbit of Telstar I.

In providing additional shielding, special attention will be given to insuring greater protection for the command circuit. This circuit receives a series of coded signals from the ground stations and "readies" the satellite for communications — the last signal, in effect, turns on the receiver and transmitter. Radiation damage to this command circuit was the reason that no communications functions were carried on via Telstar I for six weeks.

The availability of a modified Thor Delta Rocket, more powerful than that used for Telstar I, makes possible a higher and more suitable orbit. The altered orbit could be meaningful, Bell Laboratories believes, if Telstar II could be exposed to less of the high energy levels of the electron radiation in the inner Van Allen Belt.

Also, a modification will be made in the radiation package to be used in Telstar II, and this should give additional information on radiation in space.

Under terms of the launch agreement, A.T.&T. will provide NASA with complete scientific data, much of which may be valuable in planning communications satellites programs. Also, all experimental data and progress reports will be made available to the general scientific community by Bell Laboratories.

Telstar I was launched July 10, 1962. Since that date, it has been furnishing telemetry information on its own condition as well as measurements on radiation and the space environment. Such information is important to the planning of any operable satellite system.